ELUCIDATING HYDROCHEMICAL PROPERTIES OF SURFACE AND GROUND WATER FOR DRINKING AND AGRICULTURAL PURPOSES IN PARTS OF LUDHIANA DISTRICT, PUNJAB, INDIA

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ABSTRACT

Ludhiana is the first metropolitan city, popularly known as "Manchester of India." located on National Highway-I, has emerged as the most vibrant and important business center of Punjab. Agriculture is the primary occupation of the inhabitants of the Ludhiana district followed by industrial activities.The vital component for agriculture viz.water (ground and surface) are getting degraded in the Ludhiana district thereby making the present drinking and agricultural system unsustainable and non-profitable.The groundwater and surface water samples were analyzed to assess various chemical and physical water quality parameters such as (pH, EC, TDS) and major elements such as (Ca^{2+}, Mg^{2+}, Na^+, K^+, SO_4^{2-}, Cl^-, NO_3^-, HCO_3^{2-}, PO_4^{3-} and F^-) were evaluated to assess its suitability for drinking purposes. Kelly's Index (KI), Permeability Index (PI) and Magnesium Ratio (MR)/ Magnesium Hazard (MH), Chloro Alkaline Indices I (CAI-I and II) were considered and calculated to check the groundwater suitability for agricultural purposes.

KEYWORDS: Groundwater, KI, PI, MR/MH ,CAI-I and II

INTRODUCTION

The chemical properties of water (groundwater and surfacewater) are very significant to study their impact on drinking and agricultural sustainability. Today both the urban and rural sectors are equally affected by both water quality and quantity. Accordingly, the United Nations has proclaimed the period 2005-2015 as the international decade as 'water for life' (UN 2004).The quality of the groundwater varies with depth of the aquifer and its proximity to the canals. In addition, the distribution of rainfall pattern also influences the hydrochemical nature of the groundwater. In general, chemistry of ground water is interrelated with geology and hydrology of the area, physico-chemical characteristics of rocks and soils through which water percolates, nature of plant cover, extent of pollution and various other regional and local factors. India is water stressed today and is likely to be water scarce by 2050 (Gupta and Deshpande 2004). India supports more than 16% of the world's population with only 4% of the world's fresh water resources (Singh 2003). The assessment of ground and surface water quality status is important for socio-economic growth and development (Ishaku 2011).

Punjab has always been at the forefront in the development story of India. Punjab – "The Food basket and Granary of India", covers an area of 50,362 square kilometers which is about 1.53% of the total area of the

country. Geographically, Ludhiana district lies between North Latitude 30°-34' and 31°-01' and East longitude 75°-18' and 76°-20'. It is the most centrally located district of Punjab. Ludhiana is the first metropolitan city, popularly known as "Manchester of India." located on National Highway-I, has emerged as the most vibrant and important business center of Punjab.

The Central Pollution Control Board in collaboration with the Ministry of Environment and Forests identified 88 critically polluted clusters in India; Ludhiana is one of them as per EIA notification dated 14/09/2006. Agriculture is the primary occupation of the inhabitants of the Ludhiana district followed by industrial activities. About 82% of the total geographical area of the district is under cultivation. Of the total eleven developmental blocks, the five blocks (Ludhiana I, Ludhiana II, Samrala, Khanna and Doraha) are the most exploited blocks while the Machhiwara is the least exploited block. The vital component for agriculture viz. water (ground and surface) are getting degraded in the Ludhiana district thereby making the present agricultural system unsustainable and non-profitable (Sharda et al. 2015).

METHODOLOGY

44 groundwater samples and 22 surface water samples have been collected from various water sources of Ludhiana district during the Months of May 2012 and 2013 and November 2012 and 2013. The samples from these areas have been collected from varying depths of 2.5 meters to 110 meters. Sampling, preservation and analytical protocols were conducted by standard methods. Good qualities, air tight plastic bottles with cover lock were used for sample collection and safe transfer to the laboratories for analysis. The groundwater and surface water samples were analyzed to assess various chemical and physical water quality parameters such as (pH, EC, TDS) and major elements such as (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, SO_4^{2-}, Cl^{-}, NO_3^{-}, HCO_3^{2-}, PO_4^{3-} and F^{-}) were evaluated according to the standard method (APHA, 2005) within a short period of time to get a more reliable and accurate results. Physical parameters like EC, pH, TDS were measured on the spot at the time of sample collection using potable soil and water analysis kit. Analysis were done for major cations (Na^{+}, K^{+}, Ca^{2+} and Mg^{2+}) and anions (HCO_3^{2-}, Cl^{-}, SO_4^{2-}, PO_4^{3-} and NO_3^{-}) using APHA method. Ca^{2+}, Mg^{2+}, CO_3^{2-} and HCO_3^{2-} were analyzed by titration. Na^{+} and K^{+} were measured by flame photometry and NO_3^{-} and SO_4^{2-} by U.V. Spectrophotometer. Figure 1 and 2 shows the ground and surface water sampling locations during pre and post-monsoon. (2012-13).
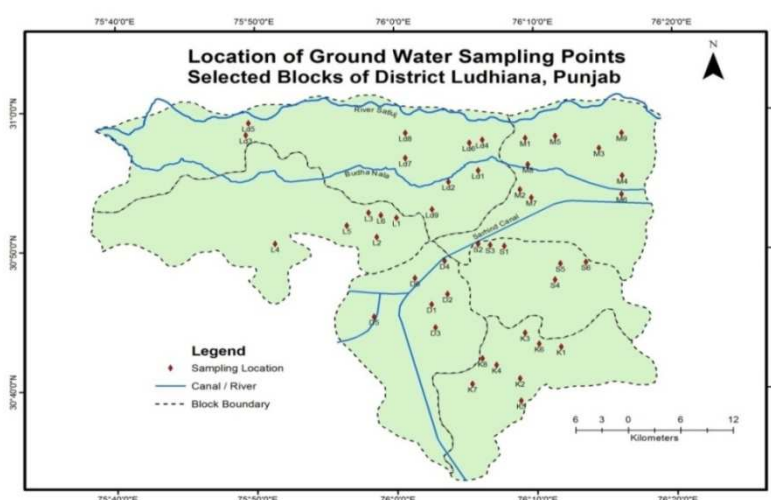
Figure 1: Groundwater Sampling Points of the Study Area during Pre and Post Monsoon
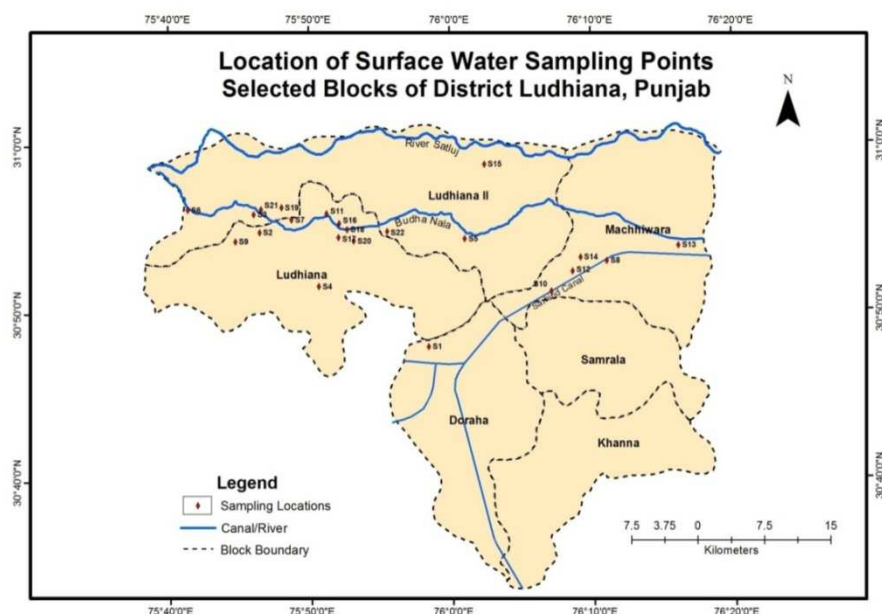
Figure 2: Surface Water Sampling Points of the Study Area during Pre and Post Monsoon

RESULTS AND DISCUSSIONS

Suitability of Groundwater and Surface Water for Drinking Purposes

Table 1and 2 shows the summary statistics of ground and surface water sampled in the study area.

Table 1: Suitability of Groundwater Sampled in the Study Area for Drinking Purposes

Parameters	Maximum Permissible Limit for Drinking Water	Maximum Desirable Limit for Drinking Water	No. of Ground Water Samples Analyzed	No. of Samples Above Permissible Limit	No. of Samples Above Desirable Limit/ %
EC	0-2000µS/cm	750µS/cm	44	Nil	09 / 20.45%
TDS	2000mg/l	500mg/l	44	Nil	32/ 72.72%
pH	No Relaxation	6.5 -8.5	44	Nil	Nil
Ca^{2+}	200mg/l	75mg/l	44	Nil	21 / 47.72%
Mg^{2+}	100 mg/l	30 mg/l	44	Nil	12 / 27.27%
Na^+	200mg/l		44	Nil	Nil
K^+	12 mg/l		44	Nil	Nil
Cl^-	1000mg/l	250mg/l	44	Nil	Nil
F^-	1.5 mg/l	1 mg/l	44	Nil	03 / 6.81%
SO_4^{2-}	400 mg/l	200 mg/l	44	Nil	Nil
NO_3^-	No relaxation	45mg/l	44	Nil	08 / 18.18%

Table 2: Suitability of Surface Water Sampled in the Study Area for Drinking Purposes

Parameters	Maximum Permissible Limit for Drinking Water	Maximum Desirable Limit for Drinking Water	No. of Surface Water Samples Analyzed	No. of Samples above Permissible Limit / %	No. of Samples above Desirable Limit / %
EC	0-2000µS/cm	750µS/cm	22	10 / (45.45)%	Nil
TDS	2000mg/l	500mg/l	22	Nil	10 / (45.45)%
pH	No Relaxation	6.5 -8.5	22	Nil	Nil
Ca^{2+}	200mg/l	75mg/l	22	Nil	02/ (9.09)%

Table 2: Contd.,					
Mg^{2+}	100 mg/l	30 mg/l	22	Nil	06 / (27.27)%
Na^+	200mg/l		22	Nil	Nil
K^+	12 mg/l		22	Nil	14/ (63.63)%
Cl^-	1000mg/l	250mg/l	22	Nil	Nil
F^-	1.5 mg/l	1mg/l	22	Nil	08 / (36.36%)%
SO_4^{2-}	400 mg/l	200 mg/l	22	Nil	Nil
NO_3^-	No relaxation	45mg/l	22	Nil	16 / (72.72)%
COD	No guidelines	---------	22	-------	-------
BOD	2mg/l	----------	22	16/ (72.72) %)	--------

Water Quality Indices for Agricultural Purposes

Kelly's Index (KI), Permeability Index (PI) and Magnesium Ratio (MR)/ Magnesium Hazard (MH), Chloro Alkaline Indices I (CAI-I and II) were considered and calculated by following standard equations given in the Table 3 for the groundwater during pre-and post-monsoon. There are five basic criteria for evaluating the water quality for irrigation i.e. pH, salinity hazard, sodium hazard, carbonate and bicarbonate as they relate to calcium, magnesium, sodium and chloride that may be toxic to plants (Ayers and Westcot, 1985). The widely accepted and widely used method, such as Piper trilinear plot is used to assess the suitability of water quality for agriculture.

Table 3: Common Indices for Agricultural Water Quality Evaluation

S. No.	Water Quality Indices	Sources
1	PI= ((Na^+ + $\sqrt{HCO_3^-}$)x100)/ (Ca^{2+}+Mg^{2+}+Na^+)	Doneen (1964)
2	KI= Na^+/ (Ca^{2+} + Mg^{2+})	Kelly (1963)
3	MR= (Mg^{2+}x100)/ (Ca^{2+} + Mg^{2+})	Paliwal (1972)
4	CAI 1 = Cl^- - (Na^++ K^+)/ Cl^- CAI 11 = Cl^- - (Na^++ K^+)/ SO_4^{2-} + HCO_3^- + CO_3^{2-}+ NO_3^-	Schoeller (1965)
* all cations and anions are expressed in meq/l		

- According to Kelly (1963) and Paliwal (1972) KI more than 1 indicates an excess level of sodium in water and is unsuitable and less than 1 are suitable for agriculture. The values of KI in studied samples were less than 1 indicating that groundwater is suitable for agriculture.

- Doneen (1964) evolved a criterion for assessing the suitability of water for agriculture based on Permeability Index (PI). According to PI value, water can be classified as ClassI, ClassII and Class III. The PI value of the most of the studied water samples falls under ClassII category which means that water is good for agricultural purposes as shown in Figure 3 a and b.
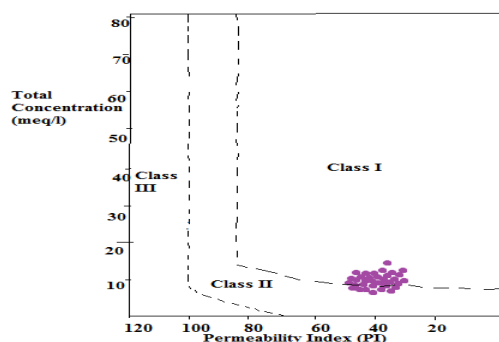

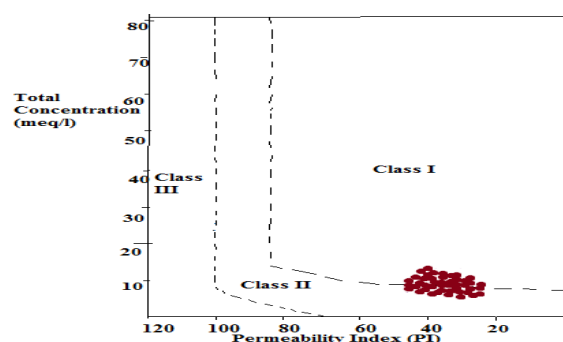**Figure 3a: Permeability Index of Groundwater Pre-Monsoon**

Figure 3b: Permeability Index Groundwater Post-Monsoon

- Calcium and magnesium normally maintain the equilibrium in most of the water ecosystems. More is the concentration of magnesium, more effect on the crop yields (Sundary et al., 2009). Magnesium hazard (MH)/ Magnesium Ratio (MR) more than 50% indicated that water is unsuitable for agriculture and thus adversely affect the crop (Paliawal, 1972). The MR value ranged from 36.68meq/l to 45.23meq/l indicated that water is suitable for agriculture. The calcium/magnesium ratio is more than 1 which means that groundwater is calcium dominant.

- All the groundwater samples during pre-and post-monsoon have negative value of CAI-I and CAI-II which indicates that there is exchange between sodium and potassium (Na^+-K^+) in water with calcium and magnesium (Ca^{2+}- Mg^{2+}) in the rocks by a type of base-exchange reactions is suitable for agricultural purposes (Brindha et al., 2014) as shown in Figure 4 a and b.

a Pre-Monsoon   **b Post-Monsoon**
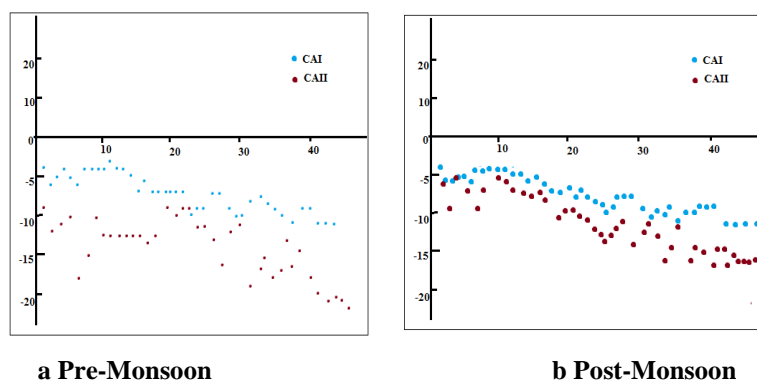
Figure 4: a and b Chloro Alkaline Indices CAI-I and II of Groundwater

Piper Trilinear Classification

Piper (1944) has developed a form of trilinear diagram, which is an effective tool in segregating analysis data with respect to sources of the dissolved constituents in groundwater, modifications in the character of water as it passes through an area and related geochemical problems. The diagram is useful in presenting graphically a group of analysis on the same plot.

The diagram combines three distinct fields by plotting two triangular fields at the lower left and lower right respectively and an intervening diamond shaped field. All three fields have scales reading in 100 parts. In the triangular fields at the lower left, the percentage reacting values of the three-cation groups (Ca^{2+}, Mg^{2+}, Na^++K^+) are plotted as a single point according to conventional trilinear coordinates. The three-anion groups (HCO_3^{2-}, SO_4^{2-}, Cl^-) are plotted likewise in the triangular field at the lower right. Thus, two points on the diagram, one in each of the two triangular fields indicate the relative concentrations of the several dissolved constituents of a groundwater. The central diamond-shaped field is used to show the overall chemical character of the groundwater by a third single point plotting which is at intersection of rays projected from the plotting of cations and anions. The position of this plotting indicates the relative composition of a groundwater in terms of cation-anion pairs that correspond to the four vertices of the field. The three areas of plotting show the essential chemical character of groundwater according to the relative concentrations of its constituents.

The chemical quality data are used in Piper's Trilinear Diagram for the graphical analysis as shown in Figure 5 a and b. The groundwater samples fall in various segments of the diamond shaped field of the Piper Diagram as shown in Table 4.

Table 4: The Quality of Groundwater Based on Piper Trilinear Diagram

Various Segments of the Diamond Shaped Field	Characteristics of Corresponding Each Small Parts of Diamond
1	Alkaline earth ($Ca^{2+}+Mg^{2+}$) exceeds alkalies ($Na^{+}+K^{+}$)
2	Alkalies exceeds alkaline earths
3	Weak acids ($CO_3^{2-}+HCO_3^{2-}$) exceeds strong acids ($SO_4^{2-}+Cl^{-}+F^{-}$)
4	Strong acids exceeds weak acids
5	Carbonate hardness (Secondary Salinity) exceeds 50%
6	Non-carbonate hardness (secondary Salinity) exceeds 50%
7	Non Carbonate alkali (Primary Salinity) exceeds 50%
8	Carbonate alkali (Primary alkalinity) exceeds 50%
9	None of the cation or anion pairs exceed 50%

The plot of chemical data on Trilinear diagram reveals that majority of the groundwater fall in the fields of 1,3,5 suggesting that alkaline earth exceeds alkalies and weak acids exceeds strong acids respectively. The ions representing carbonate hardness (secondary alkalinity) exceeds 50%, that is, the total hydro chemistry is dominated by alkaline earths and weak acids. However, a few groundwater samples fall in the 4 and 6 fields indicating strong acids exceeds weak acids and non-carbonate hardness (secondary alkalinity) exceeds 50 per cent. Some samples also fall in the field 9 indicating mixed water having no one cation-anion pair exceeds 50 percent. The results indicate that groundwater belongs to calcium magnesium and bicarbonate waters and there is no salinity and alkalinity hazard in the area.
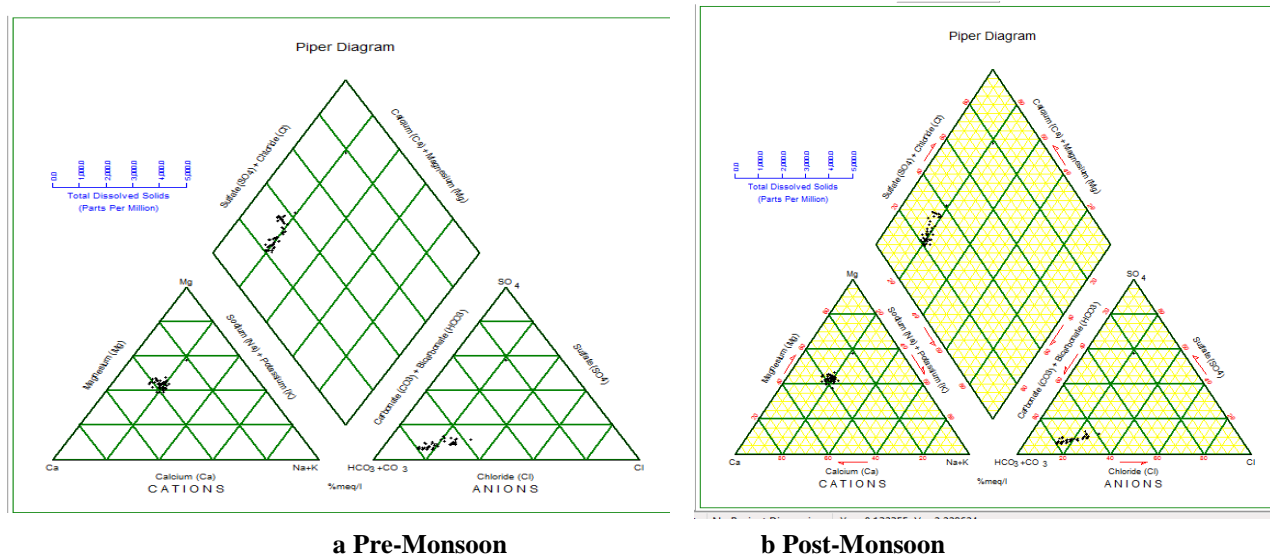

a Pre-Monsoon   b Post-Monsoon

Figure 5: a and b Piper Plot of Groundwater Samples of the Study Area

CONCLUSIONS

- The results shows that 20.45%, 72.72%, 47.72%, 27.27%, 6.81% and 18.18% of the total analyzed groundwater samples have parameters such as EC, TDS, Ca^{2+}, Mg^{2+}, F^{-} and NO_3^{2-} above the desirable limit.

- The results in Table 4.24 also indicates that 45.45%, 9.09%, 27.27%, 63.63%, 36.36% and 72.72% of the total analyzed surfacewater samples have parameters such asTDS, Ca^{2+}, Mg^{2+}, K^{+}, F^{-} and NO_3^{2-} above desirable limits and 45.45% of EC and 72.72% of BOD samples are above the permissible limit and are hence unfit for human

consumption.

- The values of KI in studied samples are less than 1 which revealed that groundwater is suitable for agriculture.

- The PI value of the most of the studied water samples falls under Class II category which means that water is good for agricultural purposes.

- The MR value ranged from 36.68meq/l to 45.23meq/l indicated that water is suitable for agriculture. The calcium/magnesium ratio is more than 1 which means that groundwater is calcium dominant.

- All the groundwater samples during pre-and post-monsoon have negative value of CAI and CAII which indicates that there is exchange between sodium and potassium (Na^+-K^+) in water withcalcium and magnesium (Ca^{2+}-Mg^{2+}) in the rocks by a type of base-exchange reactions.

- The results of the Piper plot revealed that groundwater belongs to calcium magnesium and bicarbonate waters and there is no salinity and alkalinity hazard in the area.

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